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Above Ground Gamma Ray Logging of Edgemont, South Dakota and Vicinity

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At the request of the U.S. Nuclear Regulatory Commission, the town of Edgemont, South Dakota and vicinity was surveyed in 1978 to determine if uranium mill tailings from the former Edgemont Uranium Mill had been used for off-site construction or other purposes since a similar survey conducted in 1972. Sixteen additional possible tailings use locations were found during the 1978 survey.

This report summarizes the results of the 1971-72 and 1978 surveys to locate suspected tailings use areas. It also presents and discusses other gamma measurements made in and around Edgemont.

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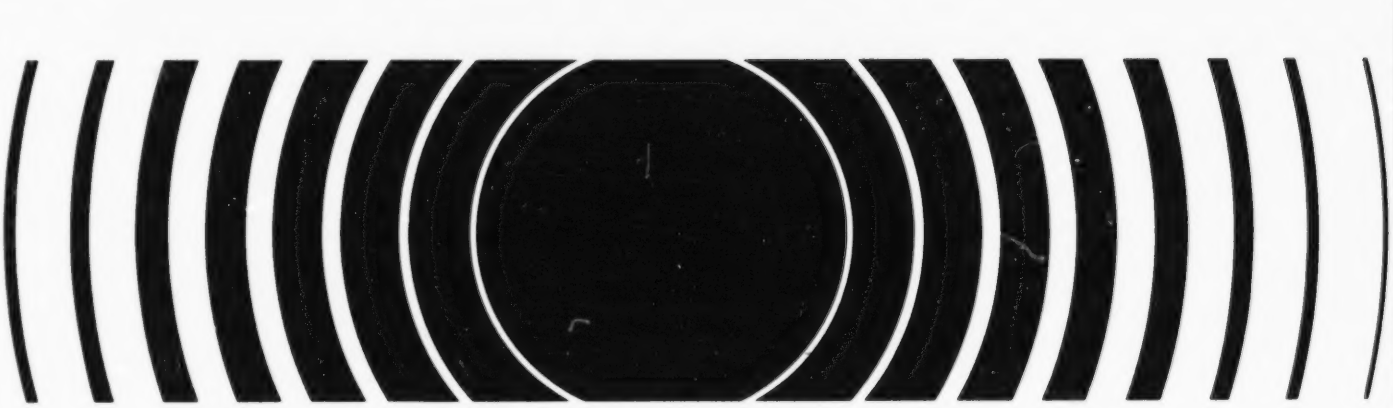

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ABOVE GROUND GAMMA RAY LOGGING OF EDGEMONT, SOUTH DAKOTA AND VICINITY

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February 1980

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PREFACE

The Office of Radiation Programs of the U.S. Environmental Protection Agency carries out a national program designed to evaluate population exposure to ionizing and non-ionizing radiation, and to promote development of controls necessary to protect the public health and safety. This report presents results from mobile gamma ray logging of several communities in the state of South Dakota to locate areas or structures containing uranium mill tailings. Readers of this report are encouraged to inform the Office of Radiation Programs of any omissions or errors. Comments or requests for further information are also invited.

Donald W. Hendricks
Director, Office of
Radiation Programs, LVF

ABSTRACT

At the request of the U.S. Nuclear Regulatory Commission, the town of Edgemont, South Dakota and vicinity was surveyed in 1978 to determine if uranium mill tailings from the former Edgemont Uranium Mill had been used for off-site construction or other purposes since a similar survey conducted in 1972. Sixteen additional possible tailings use locations were found during the 1978 survey.

This report summarizes the results of the 1971-72 and 1978 surveys to locate suspected tailings use areas. It also presents and discusses other gamma radiation measurements made in and around Edgemont.

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To Dave Duncan, Lucius Pitkin Inc., and all the unknown heros of the 1971-72 survey, our thanks for a job well done.

INTRODUCTION

Uranium ore contains, in addition to uranium, radioactive members of the uranium decay chain. Most of the uranium is removed from the ore during the milling process, and the majority of the other radioactive nuclides are discharged in the primary milling wastes. These wastes (tailings) consist of sands and slimes which have been used in many communities in the past for construction and other purposes. Gamma radiation, emitted from the wastes, can be a source of human whole-body exposure. Internal exposure may result from the inhalation or ingestion of the wastes or inhalation of the short-lived radioactive progeny of radon-222.

Although the wastes may have relatively low concentrations of radioactive materials, their use for construction purposes generally brings them close to humans for prolonged periods of time. This can cause radiation exposures in excess of normal background exposures for the general population and increase the risks of radiation induced health effects. In some cases, corrective action may be necessary to reduce radiation exposures at locations where mill tailings have been used. The evaluation of the radiological impact and of the possible need for the corrective actions is to locate those structures or areas where tailings have been used.

The Edgemont Uranium Mill (EUM) was constructed in 1956 and was operated by Mines Development, Inc., a subsidiary of Susquehanna Western, Inc. The initial capacity of the EUM was 250 tons of ore per day, this capacity was expanded within a year to 500 tons per day.

The original process for uranium extraction from the ore involved acid leaching, resin-in-pulp (RIP) ion exchange, and neutralization of the pregnant solution with magnesium oxide for precipitation. Facilities for separating and recovering molybdenum byproducts were added to the circuit as sufficient amounts of molybdenum became present in the lignite ash that also was proces-

sed for uranium. In 1960, a vanadium circuit was added and additional vanadium was recovered from reclaimed RIP slime tailings by acid leaching and solvent extraction.

Uranium recovery initially averaged 95 percent but towards the end of operations the recovery averaged 90 percent. Vanadium recovery from the ore averaged 75 to 80 percent. The U_3O_8 content of the ore averaged 0.20 percent with a relatively low vanadium content of about 0.25 percent V_2O_5. The bulk of the uranium output was produced under contract with the former U.S. Atomic Energy Commission.

At one time nearly 10 percent of the ore fed to the EUM was uraniferous ash derived from the burning of lignite coal near Belfield, North Dakota. The lignite ash contained an average of 0.35 percent U_3O_8 and 0.25 to 0.35 percent molybdenum. Most of the ore processed at the EUM was mined in the Black Hills area of South Dakota, Wyoming, and Washington State (FBDU, 1978).

At the request of the U.S. Nuclear Regulatory Commission (NRC), the U.S. Environmental Protection Agency, Office of Radiation Programs-Las Vegas Facility (ORP-LVF) conducted a radiation survey of Edgemont, South Dakota and vicinity, during November 6-8, 1978. Figure 1 is an aerial photograph of Edgemont, SD and vicinity. The primary purpose of the survey was to determine if any off-site uranium mill tailings use had occurred at locations other than those previously identified during a similar survey conducted during 1971 and 1972. To perform these surveys, a mobile gamma scanning van containing a sensitive gamma ray detector was used to locate anomalous gamma radiation levels. The anomalies were then further investigated to determine their cause.

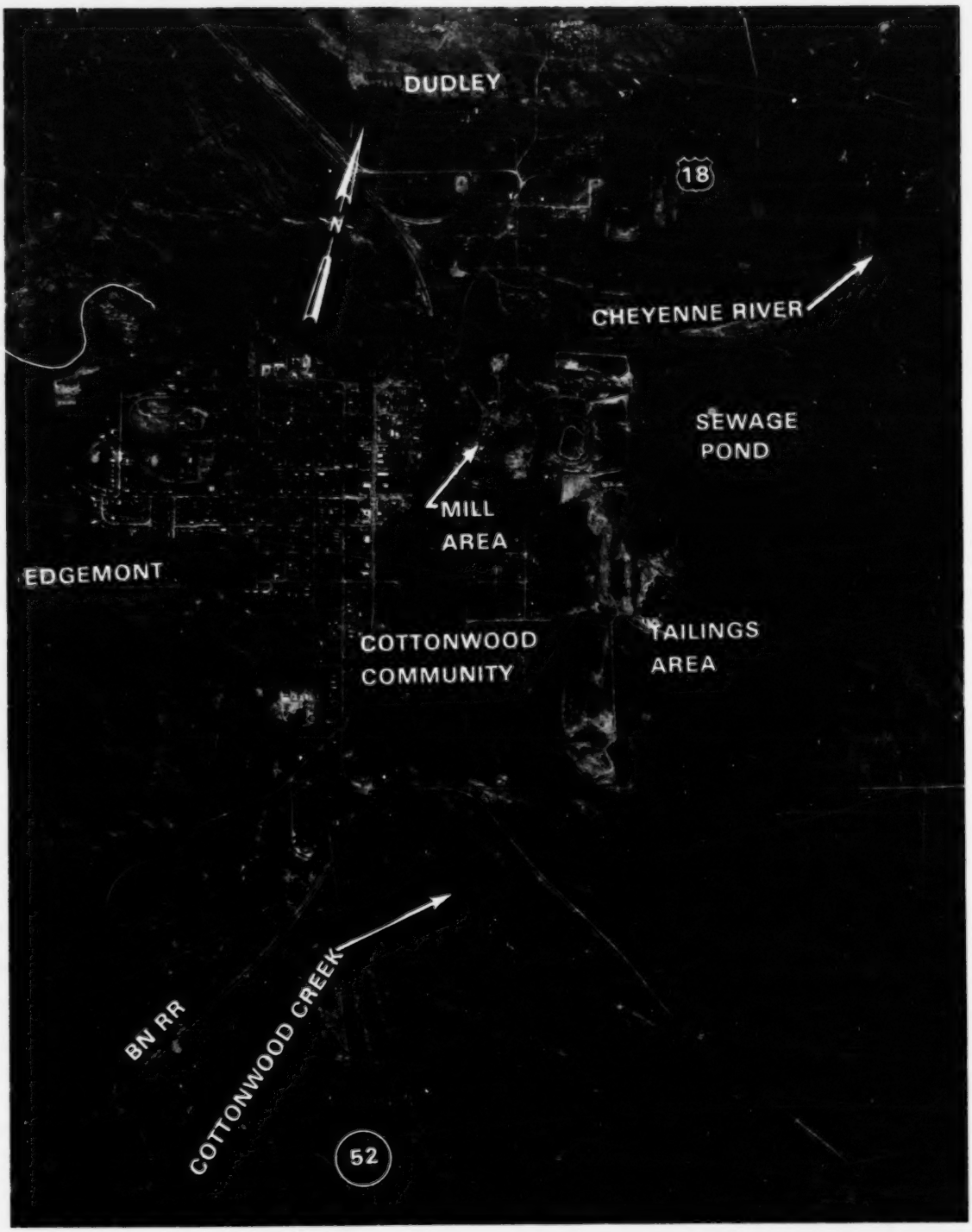

Figure 1. Aerial Photograph of Edgemont, SD & Vicinity

SUMMARY AND CONCLUSIONS

A total of 145 gamma radiation anomalies were identified by mobile logging in the Edgemont, South Dakota vicinity during the 1971-72 and 1978 surveys. Forty-four of the anomalies identified during the 1971-72 logging survey were determined to be possible tailings use locations. Sixteen additional locations were identified as having possible tailings use during the 1978 logging survey. It appears that some additional uranium mill tailings may have been used since the 1971-72 survey. It is possibe that some of the tailings locations found in the 1978 survey were missed during the 1971-72 survey because they were shielded by objects or earth.

All suspected tailings use locations found during the 1978 survey were listed as "possible tailings use" and are considered as having tailings unless they are shown to be otherwise by sample analysis and further measurements. The reason for this is that it appears that mine wastes have been used in the Edgemont school area and could have been used at other locations. Mine waste use may be resolved by analyzing samples to determine if their uranium content is depleted.

Log-normal plots of ambient gamma radiation levels in Edgemont and Dudley appear to indicate near background levels except for the First and Second Avenue areas; the verified anomaly locations; and the Edgemont school area. Two additional areas, located on the west side of Edgemont, recently had some of their topsoil removed. Comparison of gamma measurements in the scraped and undisturbed areas indicate that the topsoil may be contaminated with radionuclides. These areas should be further investigated.

Gamma radiation surveys in Cottonwood indicate that this area has elevated surface contamination as a result of wind and water erosion of the nearby tailings piles. All structures in Cottonwood may be considered as tailings locations. The estimated average net gamma external exposure rate for the inhabited areas of Cottonwood is 158 mR/yr, ranging from 53 to 412 mR/yr. This does not mean, however, that gamma radiation is the only source of radiation exposure to persons living in the vicinity of the mill site. Inhalation and ingestion of airborne tailings and radon progeny will also contribute to additional human exposures. These exposure sources should be fully evaluated.

EQUIPMENT DESCRIPTION

Mobile Radiation Scanner

Since the radionuclides contained in uranium mill tailings emit abundant and relatively energetic gamma radiation, they may be detected remotely by means of a sensitive gamma radiation detector. In order to locate possible tailings use sites and to evaluate human radiation exposure, we built a mobile radiation detector. The detector was a large sodium-iodide crystal shielded on the bottom and sides to reduce terrestrial background radiation. The shield contained a port to enhance the crystal's response to gamma radiation coming from a particular direction. The detector assembly was mounted in a van-type vehicle and was operated as a gross gamma-ray-rate meter. An analog output of the rate meter was presented on a strip chart or log. While the meter output was being recorded, the log was observed for increased count rates caused by radiation sources in the proximity of the scanner. When an increased count rate or anomaly was observed on the log, the location of the vehicle was recorded by street address or other means. A more complete description of the scanner and its use is available in the literature (Hans, 1977).

The gamma ray scanning vehicle used in the 1971-72 surveys contained a modified well logging system using two 4" x 4" sodium iodide crystal detectors connected in parallel. The detectors were mounted on the top of the right rear end of the vehicle and were shielded in such a manner to observe areas to the right side.

Portable Scintillometers

Several types of portable (hand held) scintillometers were used to further investigate anomalies identified with the mobile radiation scanner. These investigations or follow-up surveys were conducted to verify, assess and more precisely locate the radioactive materials causing the anomalies. The following listing briefly describes the types of scintillometers used.

1. Ludlum Instruments Model 19 Scintillometer - This instrument, used in the 1978 survey detects gamma radiation with a small sodium iodide crystal coupled to a photomultiplier tube (PMT). The output signals from the PMT are used to drive a linear rate meter having an exposure rate range of 0-5000 μR/hr. Properly calibrated, this instrument can provide a reasonable estimate of the gamma ray exposure rate from uranium mill tailings or ore.

2. Rank (Baird Atomic) Model NE148A Scintillometer - This instrument operates basically in the same manner as the previously described scintillometer and was used for the follow-up surveys conducted in 1972.

3. Rank Model NE148A Scintillometer (modified) - This modified version was used in the 1978 follow-up surveys. The rate-meter time constant was increased to 10 seconds and a sliding lead shield assembly was attached to the instrument body. The time constant was increased to reduce meter fluctuations. The shield assembly helped to more precisely locate uranium mill tailings and ore and to estimate the degree of surface contamination.

Ion Chamber

A Reuter-Stokes Model RSS 111 ion chamber was operated in conjunction with the mobile scanner to measure gamma ray exposure rates at selected locations. The instrument consists of an ion chamber and electrometer coupled by a cable to a digital rate meter and power supply. The ion chamber is pressurized to increase its sensitivity to low level gamma exposure rates and is designed to have a reasonably flat response to most gamma ray energies of interest.

DISCUSSION OF THE 1971-72 SURVEY

Edgemont - Dudley - Cottonwood - Provo - Hot Springs (South Dakota)

A mobile gamma scanning unit was operated by the U.S. Atomic Energy Commission contractor Lucius Pitkin, Inc.,* under an interagency agreement for the U.S. Environmental Protection Agency. After the mobile gamma scan was completed, the recorder chart was forwarded to the Lucius Pitkin office in Grand Junction, Colorado, where the chart with the anomaly addresses and notes added by the operator were analyzed. An anomaly was defined as any location where the recorded counts per second (c/s) exceeds the pre-determined background by 50 c/s. The anomaly report was sent to the National Environmental Research Center-Las Vegas (NERC-LV)** and, in turn, forwarded to the South Dakota Department of Health. Field teams used this report to conduct follow-up surveys at each anomaly location. Table 1 lists, by location, the results of this survey. Appendix B gives the physical location of the anomalies in Edgemont and Appendix C gives the physical location of the anomalies in Dudley.

The field teams were composed of two persons, each equipped with a portable radiation survey instrument. These instruments were calibrated at the NERC-LV and a five-item field check was performed each day to determine if the instrument was functioning properly. If the instrument did not operate within pre-set ranges, it was not used.

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* Lucius Pitkin, Inc., Contractor for the Grand Junction, Colorado, Operations Office of the former U.S. Atomic Energy Commission (now Department of Energy)

** NERC-LV is now EPA Environmental Monitoring Systems Laboratory-Las Vegas (EMSL-LV)

TABLE 1. FOLLOW-UP SURVEYS OF THE ANOMALIES IDENTIFIED DURING THE 1971-72 SURVEY

LOCATION NUMBER+	HOG*	LOG**	HIG***	C O M M E N T S
40 - 500	70	10	NR****	Tailings north side of house
501	40	10	NR	Tailings in front and south front of house
502	100	9	NR	Tailings east side of building
503	15	12	11	Radium source
504	50	40	18	Wind blown tailings entire yard
505	40	30	NR	" " " " "
506	25	20	NR	" " " " "
507	80	60	NR	" " " " "
508	50	40	NR	" " " " "
509	30	20	18	Wind blown tailings on north side of house
510	30	25	NR	Wind blown tailings on entire lot
511	30	25	NR	" " " " "
512	40	25	16	Wind blown tailings in entire yard
513	30	25	NR	Wind blown tailings on entire lot
514	50	40	NR	" " " " "
515	40	20	NR	Shine from tailings pile
516	45	15	NR	Tailings at edge of highway and railroad tracks
517	30	12	NR	Tailings at edge of highway on both sides
518	100	30	NR	Tailings entire area
519	35	20	18	Shine from tailings pile
520	30	10	10	Tailings edge of highway
521	50	12	12	Tailings in driveway
522	35	9	NR	Tailings in parking lot
523	35	16	20	Shine from mill
524	130	14	14	Tailings east side of bldg.
525	50	13	NR	Tailings east side of lot
526	21	13	14	Tailings in entire yard
527	100	14	15	Tailings in yard and possible ore sample in drive
528	20	12	11	Possible wind blown tailings
529	80	12	NR	Tailings in driveway and yard
530	21	10	NR	Wind blown tailings
531	18	12	NR	West side of building
532	22	13	17	Tailings entire yard
533	20	13	NR	Wind blown tailings entire yard
534	20	10	11	Wind blown tailings on east side of house

LOCATION NUMBER+	HOG*	LOG**	HIG***	C O M M E N T S
40 - 535	26	14	NR	Wind blown tailings entire yard
536	45	17	16	Wind blown tailings and shine
537	30	15	NR	" " " " "
538	60	14	14	Tailings in north and west yard and southeast corner
539	40	9	NR	Tailings in front lawn
540	18	9	NR	
541	16	11	NR	
542	80	13	NR	Tailings east side and north-west corner of yard
543	80	11	10	Tailings in front flower bed and back steps
544	120	9	10	Tailings in rock garden and picnic area
545	14	9	NR	
546	22	15	NR	Tailings on entire lot
547	22	15	NR	Wind blown tailings entire park
548	18	12	NR	
549	16	11	250	Ore in basement
550	>3000	15	40	Ore samples
551	27	12	14	Tailings at south side of building
552	16	10	NR	Granite cornerstone
553	100	10	NR	Tailings in gutter
554	15	12	14	
555	18	13	NR	
556	100	12	100	Tailings in basement fill and entire yard
557	150	14	NR	Tailings in front and south yard
558	16	10	NR	High outside gamma entire lot
559	50	8	8	Tailings spots in front yard
560	11	6	NR	
561	12	7	10	
562	15	9	NR	Brick
563	10	7	9	
564	12	7	NR	
565	11	6	10	
566	9	6	NR	
567	11	6	10	
568	NR	NR	NR	
569	11	6	12	Granite
570	10	5	NR	
571	15	6	10	
572	12	7	NR	
573	11	7	10	

LOCATION NUMBER+	HOG*	LOG**	HIG***	C O M M E N T S
40 - 574	11	8	10	
575	10	6	10	
576	10	5	10	Brick
577	11	9	NR	
578	13	8	NR	
579	10	8	11	Brick
580	10	7	15	HIG-shine from brick
581	13	8	NR	
582	11	7	NR	
583	12	6	NR	
584	13	6	15	
585	13	8	NR	Ore in rock garden in front yard
586	12	6	NR	
587	NR	NR	NR	
588	11	7	13	Ore samples
589	11	7	NR	
590	15	6	NR	Brick walls
591	NR	NR	NR	
592	12	8	NR	
593	10	8	NR	
594	15	11	NR	
595	12	8	NR	Brick wall
596	8	7	NR	Ore
597	14	9	NR	
598	21	8	NR	Shale and Clay
599	12	8	NR	Lower part of hillside
600	13	7	NR	
601	12	8	NR	Grassy area
602	18	7	7	Northwest corner of building and lawn
603	11	6	NR	
604	12	7	NR	

\+ Location Number
Numbers 40-504 thru 40-559 were assigned to Edgemont
Numbers 40-560 thru 40-604 were assigned to Hot Springs
Numbers 40-500 thru 40-503 were assigned to Provo

* HOG Identifies the highest outside gamma measurement recorded at that location (μR/hr)

** LOG Identifies the lowest outside gamma measurement recorded at that location (μR/hr)

*** HIG Identifies the highest gamma measurement inside the structure recorded at that location (μR/hr)

**** NR No gamma measurement was recorded

A follow-up survey was performed at a location only after permission was obtained from the owner or occupant of the property. Suspected tailings use might have been determined while approaching the property or structure to request permission. Once permission to survey was obtained, one surveyor would monitor inside the structure and his partner would monitor the surrounding outside property. A sketch of the property containing radiation measurements made at three feet from surfaces was prepared for documentation and future reference.

The mobile gamma scanning team reported sixty-one gamma radiation anomalies from 560 structures scanned in Edgemont, South Dakota. Five of the anomalies were duplicated. All of the anomalies were investigated, resulting in the preparation of fifty-six Indoor Radon Study-Gamma Screening Forms. The purpose of the form was to document the follow-up survey. Figure 2 is an example of this form.

There were eight anomalies where no elevated radiation level could be found. Three anomalies were identified as ore or direct radiation (shine) from the uranium mill tailings pile. One anomaly was identified as natural radioactivity present in granite. Forty-four of the fifty-six locations were determined as possible tailings use locations. The forty-four possible tailings use locations are identified as follows: two locations as probable tailings use; sixteen locations as having tailings greater than ten feet from the structure (tailings away-TA); twenty-five locations as having tailings within ten feet of the structure (tailings under-TU); and the Edgemont uranium mill site.

Two locations where uranium ore was found were habitable structures. Ore specimens were stored in the basement at location 40-549 and gamma measurements as high as 250 µR/hr were recorded. At location 40-550, materials that appeared to be ore specimens were stored against the outside of three walls. Gamma measurements exceeding 3,000 µR/hr were recorded next to the materials; and the "shine" from the materials produced gamma measurements as high as 40 µR/hr, inside the house. The gamma measurements recorded at location 40-552 were caused by the granite stone used in the construction of the structure.

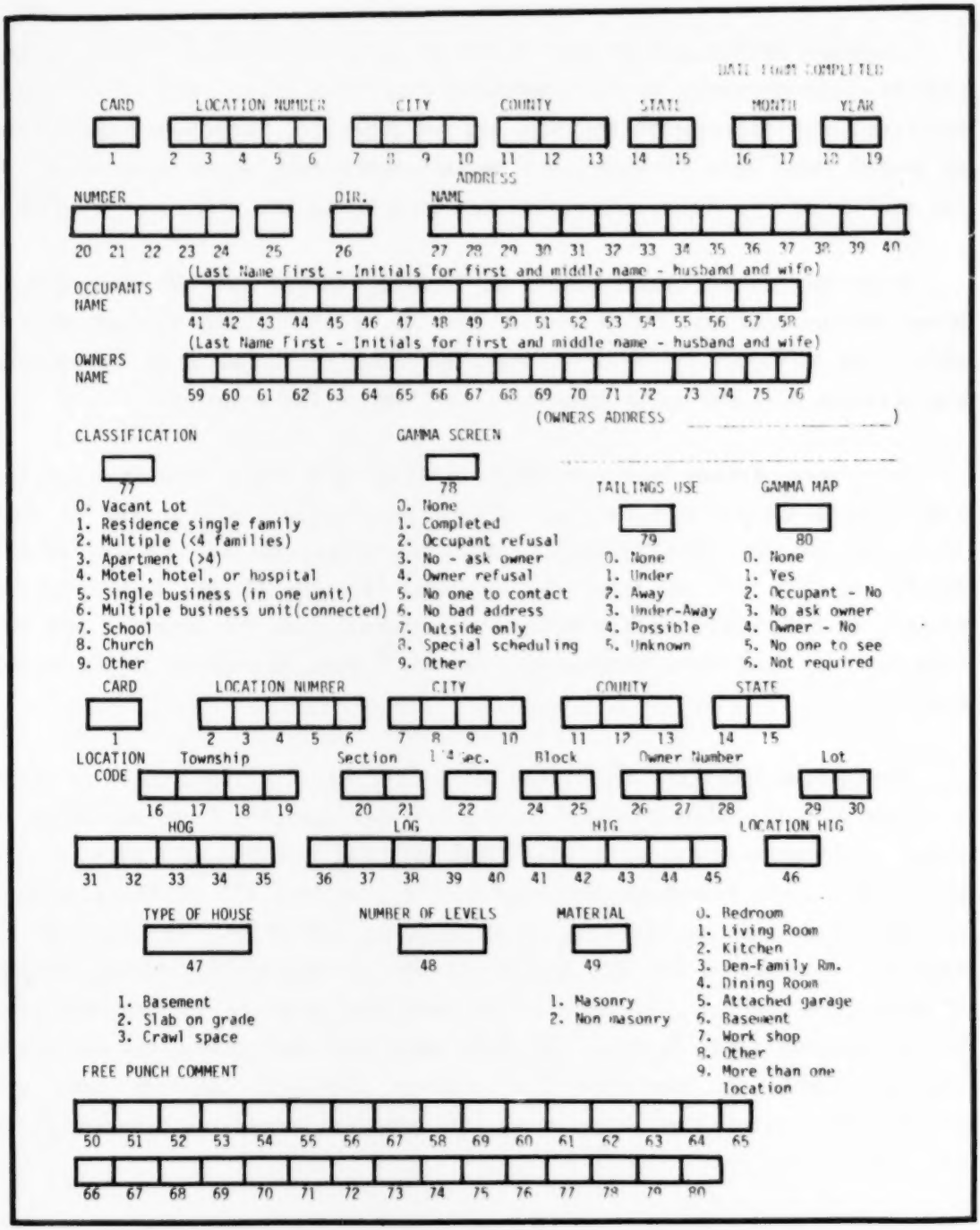

Figure 2. Indoor Radon Study-Gamma Screening Form

Locations 40-515 and 40-519, listed as possible tailings locations, were both in close proximity to the uranium mill tailings pile. Because of this, a positive identification of tailings was not possible. Gamma measurements made at ground level were 40 μR/hr; and measure-ments made about seven feet from the surface of the ground, representing "shine" from the pile, were 35 μR/hr.

Since the surface measurements at location 40-523 were 30 μR/hr and the other measurements at 3 feet and 6 feet above the ground surface were 35 μR/hr, the surveyors believed the reported anomaly was caused by "shine" from the tailings pile and not a deposit of tailings on the property.

There were sixteen locations where tailings were found more than ten feet away from a habitable structure. There were vacant lots at ten of these locations (40-508; 40-510; 40-511; 40-513; 40-514; 40-516; 40-517; 40-525; 40-546; 40-547). At the other six locations (40-520; 40-521; 40-522; 40-530; 40-544; 40-553) there were habitable structures, but the material was more than ten feet from these structures. Exposure rates as high as 120 μR/hr were measured.

Twenty-five locations are listed where tailings were found under or within ten feet of a habitable structure. The tailings deposits found at sixteen of these locations were caused by wind blown material from the mill site tailings piles. This wind migration deposited tailings against all of the structures and produced gamma exposure rates as high as 100 μR/hr. At eight of the twenty-five locations (40-524; 40-529; 40-538; 40-542; 40-543; 40-551; 40-557; 40-559), the tailings had been hauled onto the property for various uses. Gamma measurements as high as 130 μR/hr were recorded against the outside of the structures. At the remaining location (40-556), tailings were used beneath the basement floor slab or as fill material around the basement walls, and also in the yard.

The mobile gamma scanning unit reported forty-five gamma radiation anomalies from 1,178 structures scanned in Hot Springs, South Dakota. All of the anomalies were investigated, resulting in the preparation of forty-five Indoor Radon Study-Gamma Screening Forms.

There were twenty-five anomalies where nothing was found or where the resident refused permission to investigate further; three anomalies were from radioactive material present in ore; and seventeen anomalies were due to naturally occurring radioactive materials.

Uranium ore was found at three locations. At location 40-585, the ore was located in a front-yard rock garden; and gamma measurements up to 800 µR/hr were recorded. Numerous ore samples were found at location 40-588 and the gamma measurements exceeded 3,000 µR/hr. At location 40-596, the ore was on a vacant lot and appeared to be a natural geological occurrence. Gamma measurements to 250 µR/hr were recorded at this location.

The mobile gamma scanning unit reported four gamma radiation anomalies from twenty-two structures scanned in Provo, South Dakota. All of the anomalies were investigated, resulting in the preparation of three Indoor Radon Study-Gamma Screening Forms. The reported gamma anomaly at location 40-503 was due to a radium source in a sealed glass bottle inside the residence. Gamma measurements, made at the surface of the bottle, exceeded 3,000 µR/hr. The reported anomalies at the remaining three locations were apparently caused by tailings deposits. At two of these locations (40-501 and 40-502) the radioactive material was present on property which had habitable structures. However, the apparent tailings deposits were more than ten feet away. The deposit at location 40-501 was along a ditch bank and gamma measurements as high as 40 µR/hr were recorded. At location 40-502 the material was next to the street and at the driveway entrance. Gamma measurements as high as 100 µR/hr were recorded at this location. Location 40-500 was a TU location since the apparent tailings deposit was up against the north side of the residence. Gamma measurements as high as 70 µR/hr were recorded over the deposit; however, the residence was vacant at the time of the survey and the surveyors were unable to enter the structure to obtain inside measurements.

DISCUSSION OF THE 1978 SURVEY

The Edgemont area was logged with the previously described mobile scanner. The equipment operator would observe the trace being made on the recorder, watching for count rates (anomalies) above background for that immediate area being recorded. When an anomaly was observed, the street address or other identifying landmark was listed by a second person designated as an observer-recorder. This list of anomalies was then used by gamma survey teams to further investigate the anomalies.

The gamma survey teams were composed of two members. One member was equipped with a portable scintillometer and the second team member was equipped with the gamma screening form. The gamma survey instruments were calibrated at EMSL-LV calibration facility using a Ra-226 standard source traceable to the National Bureau of Standards (NBS). The Gamma survey instruments were checked everyday for proper operation. If an instrument did not check out, it was not used by the survey team.

A survey of a suspected anomaly location was performed only after permission was granted by the owner or occupant of the property. Once permission was obtained the survey team would survey the outside of the property. Radiation measurements were made at three feet above the ground level and on the surface. Sufficient radiation measurements were taken and recorded to determine the approximate boundaries of the radioactive materials. When suspected tailings were located within ten feet of a structure, an indoor gamma survey of the structure was completed and recorded. For some locations, where the occupant of the property could not be located after several tries, a quick radiation survey was done around the property boundary to try to determine if tailings were used.

The mobile scanner identified eighty-four anomalies in the communities of Dudley and Edgemont. The eighty-four anomaly locations were broken down as follows: seventeen locations identified as possible tailings use; sixteen locations identified as radiation sources other than tailings; and fifty-one

locations identified as having no radiation sources. Nine gamma radiation survey sketches were drawn for six locations; 7811-66, 7811-80, 7811-81, 7811-82, 7811-83, 7811-84. The gamma sketches are located in Appendix A. A contaminated bottom-dump earth scraper was found at location 7811-62.

Some large open areas showed significant gamma radiation differences as compared to the general background. Locations 7811-81, 7811-83, and 7811-84 were examples of these differences. Location 7811-81 was a newly constructed log building located approximately in the center of a parking lot. The parking lot had been scraped and cinders added as a top cover. The gamma measurements increased toward the south side and northeast edge of the parking lot. A pile of scrapings was located at the extreme west edge of the lot, and a gamma measurement taken on top of the pile was 25μR/hr. One commercial enterprise west of Edgemont on Highway 18 had a large scraped area with a metal building located on it. When the mobile scanner was driven into the lot the count rate dropped from about 600 counts per second (c/s) to about 400 c/s. The measurements made at both scraped areas tend to indicate the presence of surface contamination. Locations 7811-83 and 7811-84 showed significant increases above the general background. These two areas were generally undisturbed and were covered with grass and weeds. Table 2 is a listing of the anomalies identified during the 1978 survey. Appendix B gives the physical location of the anomalies in Edgemont and Appendix C gives the physical location of the anomalies in Dudley.

TABLE 2. FOLLOW-UP SURVEYS OF THE ANOMALIES IDENTIFIED DURING THE 1978 SURVEY

LOCATION NUMBER	HOG*	LOG**	HIG***	COMMENTS
7811 - 01	23	18	NR****	Anomaly not confirmed
02	23	15	NR	" " "
03	23	13	NR	" " "
04	23	14	NR	" " "
05	19	15	NR	" " "
06	19	15	NR	" " "
07	18	17	NR	" " "
08	20	16	NR	" " "
09	22	17	NR	" " "
10	20	18	NR	" " "
11	19	16	NR	" " "
12	21	17	NR	" " "
13	20	16	NR	" " "
14	20	17	NR	" " "
15	22	18	NR	" " "
16	20	16	NR	" " "
17	15	15	NR	" " "
18	18	15	NR	" " "
19	18	15	NR	" " "
20	25	15	NR	" " "
21	20	15	NR	" " "
22	15	15	NR	" " "
23	20	12	NR	" " "
24	23	17	NR	" " "
25	22	17	NR	" " "
26	20	17	NR	" " "
27	20	15	NR	" " "
28	22	18	NR	" " "
29	24	17	NR	" " "
30	23	19	NR	" " "
31	23	17	NR	" " "
32	22	17	NR	" " "
33	15	15	NR	" " "
34	15	15	NR	" " "
35	15	15	NR	" " "
36	20	15	NR	" " "
37	20	15	NR	" " "
38	18	11	NR	" " "
39	NR	NR	NR	Shine from next lot east
40	20	17	NR	Anomaly not confirmed
41	23	19	NR	" " "
42	18	13	NR	" " "
43	19	14	NR	" " "
44	20	15	NR	" " "
45	23	16	NR	" " "

LOCATION NUMBER	HOG*	LOG**	HIG***	COMMENTS
7811 - 46	23	18	NR	Anomaly not confirmed
47	23	18	NR	" " "
48	17	17	NR	Ore samples in trailer behind house
49	200	15	NR	Rock in backyard
50	25	14	NR	Brick building
51	27	17	NR	Sandstone foundation and rock garden
52	120	17	NR	Possible ore in basement
53	44	17	NR	Rock-possible ore
54	250	18	NR	Small area in back yard -possible ore
55	1000	14	NR	Rock-possible ore
56	23	18	NR	Sand in flower bed-possible tailings use
57	90	17	NR	Rock in yard-possible ore
58	24	16	NR	Rock pile near carport -possible ore
59	34	19	NR	Hot rock and stone facing on house-possible ore
60	50	15	NR	Small spot in driveway -possible ore
61	35	15	NR	Small spot at SE corner of house-possible tailings use
62	120	35	NR	Bottom dump scraper and immediate area scraper may have been used in Cottonwood -possible tailings location
63	20	17	NR	Anomaly not confirmed
64	235	18	50	Possible ore in flower bed
65	27	18	NR	Possible tailings in backyard retaining wall
66	140	15	28	Possible tailings use in flower bed
67	220	17	NR	Fill hauled from across street-possible tailings
68	200	20	NR	Backyard fill-possible tailings
69	50	16	NR	Backyard fill-possible tailings
70	70	20	NR	Fill in yard-possible tailings
71	60	15	NR	Fill in yard-possible tailings
72	30	17	NR	Possible tailings use in yard
73	40	17	NR	Possible tailings use in parking lot

LOCATION NUMBER	HOG*	LOG**	HIG***	COMMENTS
7811 - 74	40	17	NR	Stucco-brick and petrified wood-possible use of tailings in stucco
75	25	16	NR	Possible tailings use in cement
76	18	13	NR	Anomaly not confirmed
77	23	17	NR	" " "
78	22	19	NR	" " "
79	23	12	NR	" " "
80	240	17	49	Fill along basement wall -possible tailings use
81	28	18	NR	Possible mine wastes
82	60	15	NR	Flower bed-possible tailings use
83	23	17	NR	Possible mine wastes
84	20	16	NR	Possible mine wastes

* High Outside Gamma (μR/hr)
** Low Outside Gamma (μR/hr)
*** High Inside Gamma (μR/hr)
**** NR - No Measurements Made

DISCUSSION OF ADDITIONAL GAMMA RADIATION MEASUREMENTS MADE IN EDGEMONT AND VICINITY DURING THE 1978 SURVEY

A Reuter-Stokes Model RSS-111 pressurized ion chamber (PIC) was carried and operated in the mobile scanner van during the 1978 survey. The ion chamber detector was placed on the floor in the rear of the van and its read-out unit was placed in the front of the van for viewing access. Most of the PIC measurements were made on street intersections and measurements were made each time the van entered an intersection. Consequently, more than one PIC measurement generally was made at each intersection.

Some gamma ray shielding of the ion chamber occurs from the van structure (i.e., metal floor and frame). The shielding factor for the van was previously determined to attenuate the ambient exposure rate by 17 percent.

PIC measurements made in Edgemont, Dudley, and Cottonwood are listed in Table 3. The table contains the measurement locations, gross exposure rates at each location, and the exposure rates corrected for van shielding. The physical location of the PIC measurements for Edgemont and Dudley are given in Appendices B and C respectively.

All corrected exposure rates are plotted on log-probability paper to determine their distribution characteristics (Figure 3, Plot A). The data on plot A belongs to two distributions which end and begin near the 70 percentile line. All data below the 74 percentile line were ranked and plotted (Plot B). The slope or Standard Geometric Deviation (SGD) of Plot B is 1.04 and strongly indicates that the data in this group indicates background conditions (Denham, 1975). A relatively uniform deposition of mill wastes over the Edgemont area would also produce a similar SGD. The geometric average ($\overline{X}g$) or 50 percentile value for Plot B is about 12 μR/hr. Therefore, the ambient gamma radiation background in Edgemont and Dudley was about 12 ± 1 μR/hr at the 95 percent confidence level. The geometric average compares well with the arithmetic average of 12.4 μR/hr computed in Table 3.

TABLE 3. PIC MEASUREMENTS EDGEMONT, DUDLEY, COTTONWOOD

EDGEMONT

LOCATION	NUMBER OF MEASUREMENTS	AVERAGE EXPOSURE RATE (μR/hr)	CORRECTED AVERAGE EXPOSURE RATE (μR/hr)
"A" St. 2nd Ave.	3	10.0	11.7
3rd Ave.	2	9.9	11.5
4th Ave.	3	9.6	11.3
5th Ave.	3	10.4	12.2
6th Ave.	4	9.8	11.4
7th Ave.	4	10.5	12.3
10th Ave.	2	11.2	13.1
"B" St. 2nd Ave.	2	10.7	12.5
3rd Ave.	4	10.3	12.0
4th Ave.	4	10.2	11.9
5th Ave.	4	10.8	12.6
6th Ave.	4	9.9	11.6
7th Ave.	4	10.5	12.3
"C" St. 2nd Ave	4	9.8	11.4
3rd Ave.	4	10.5	12.3
4th Ave.	4	10.8	12.6
5th Ave.	4	10.7	12.6
6th Ave.	4	10.3	12.1
7th Ave.	4	10.2	11.9
10th Ave.	4	12.2	14.2
"D" St. 2nd Ave.	3	10.0	11.7
3rd Ave.	4	10.3	12.0
4th Ave.	4	10.2	11.9
5th Ave.	4	10.5	12.2
6th Ave.	4	10.0	11.7
7th Ave.	4	10.8	12.6
10th Ave.	1	12.2	14.3

LOCATION	NUMBER OF MEASUREMENTS	AVERAGE EXPOSURE RATE (μR/hr)	CORRECTED AVERAGE EXPOSURE RATE (μR/hr)
"E" St. 2nd Ave.	4	10.1	11.9
3rd Ave.	4	10.1	11.8
4th Ave.	4	10.4	12.2
5th Ave.	4	10.3	12.1
6th Ave.	4	10.0	11.7
7th Ave.	5	10.2	12.0
8th Ave.	3	10.9	12.8
9th Ave.	3	11.0	12.9
10th Ave.	3	11.0	12.9
"F" St. 2nd Ave.	5	9.7	11.4
3rd Ave.	4	10.2	11.9
4th Ave.	4	9.9	11.6
5th Ave.	4	11.3	13.2
6th Ave.	5	10.7	12.5
7th Ave.	5	10.8	12.6
8th Ave.	3	11.1	13.0
9th Ave.	2	11.2	13.1
"G" St. 2nd Ave.	4	10.5	12.3
3rd Ave.	5	10.3	12.1
4th AVe.	4	10.3	12.1
5th Ave.	4	11.3	13.3
6th Ave.	6	10.9	12.7
7th AVe.	2	11.1	12.9
"H" St. 2nd Ave.	1	9.3	10.9
3rd Ave.	4	9.7	11.4
4th Ave.	5	10.2	12.0
5th Ave.	3	10.4	12.1
6th Ave.	2	10.5	12.2

LOCATION	NUMBER OF MEASUREMENTS	AVERAGE EXPOSURE RATE (μR/hr)	CORRECTED AVERAGE EXPOSURE RATE (μR/hr)
"H" Extension			
City Well No. 2	1	10.8	12.6
Hospital	1	9.3	10.9
Airport	1	11.6	13.6
"C" St. School			
Alley	2	12.3	14.2
School Complex	1	12.6	14.7
Ball Field	1	13.0	15.2
"E" and "F" Streets	3	10.8	12.7
Cul-de-sac off "C" Street	1	12.0	14.0
West Side Railroad			
at Route 18	1	12.0	14.0
" "A" Street	2	11.5	13.4
" "B" Street	1	11.2	13.1
" "C" Street	1	11.0	12.9
" "D" Street	1	11.4	13.3
" "E" Street	1	10.6	12.4
North End 4th Avenue	1	11.7	13.7
" " 5th Avenue	1	10.7	12.5
3rd and Lawrence	1	9.7	11.4
4th " "	1	10.0	11.7
3rd and Hansen	1	10.2	11.9
Top of Hill Mobile Home Park, Southeast Corner of Town	1	10.0	11.7

Average 12.4

DUDLEY

LOCATION	NUMBER OF MEASUREMENTS	AVERAGE EXPOSURE RATE (μR/hr)	CORRECTED AVERAGE EXPOSURE RATE (μR/hr)
A	1	10.5	12.3
B	1	10.3	12.1
C	1	11.0	12.9
D	1	10.2	11.9
E	1	9.6	11.2
F	1	11.3	13.1
			Average 12.3

COTTONWOOD

LOCATION	NUMBER OF MEASUREMENTS	AVERAGE EXPOSURE RATE (μR/hr)	CORRECTED AVERAGE EXPOSURE RATE (μR/hr)
1	1	19.3	22.6
2	1	15.7	18.4
3	1	12.3	14.4
4	1	12.5	14.6
5	1	13.5	15.8
6	1	19.5	22.8
7	1	18.0	21.1
8	1	21.0	24.6
9	1	18.6	21.8
10	1	14.5	17.0
			Average 19.3

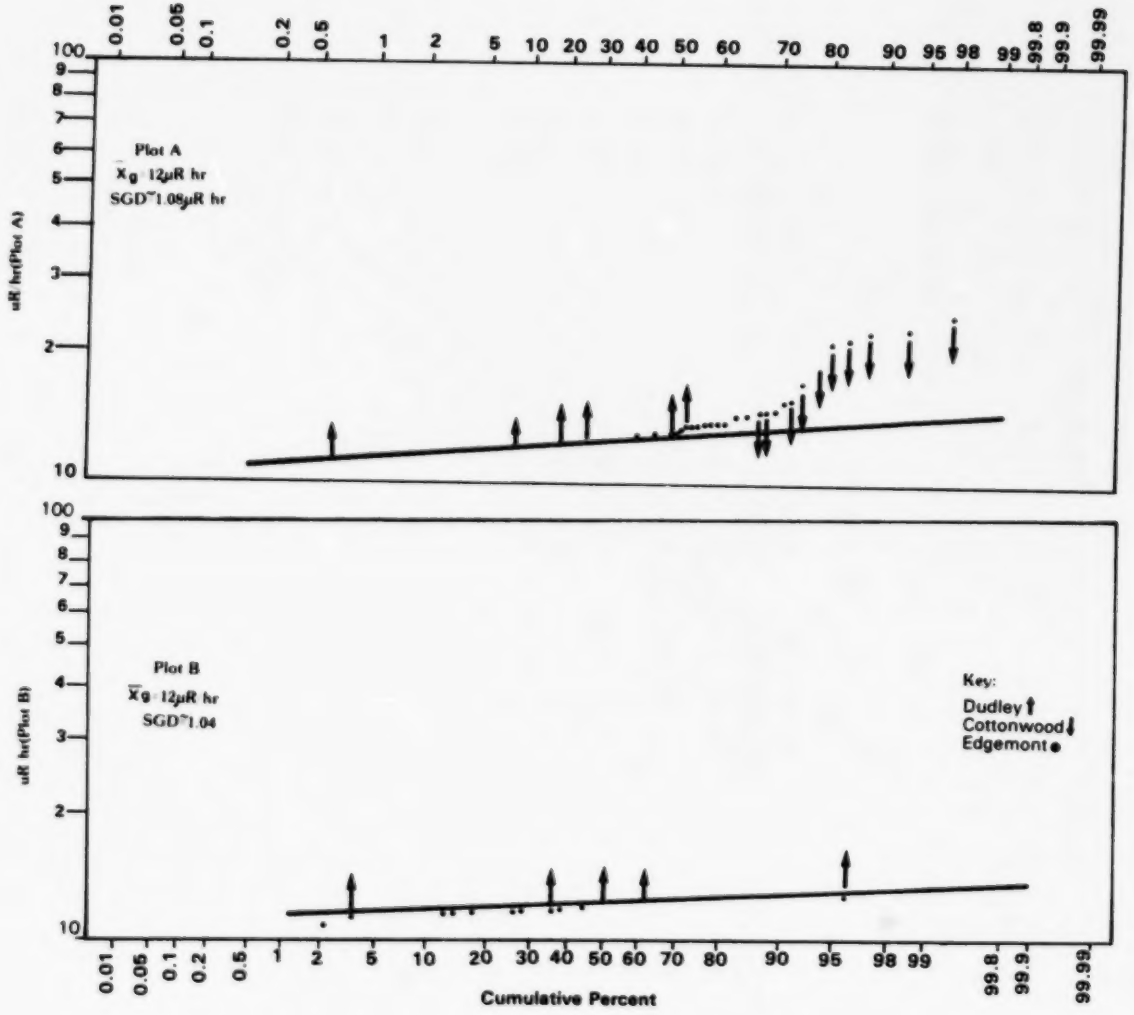

Figure 3. Log-Probability Plot of PIC Measurements

All of the PIC measurements made in Cottonwood are not in the background distribution. These measurements are discussed later in this report.

Seven PIC measurement locations in Edgemont were in excess of 13.4 μR/hr ($\overline{X}g$ + 3 SGD). These are:

1. C St. and 10th Avenue
2. C St. and school alley
3. D St. and 10th Avenue
4. C St. and school complex
5. C St. and school ballfield
6. H St. extension and airport
7. North end of Fourth Avenue

Locations 2, 4 and 5 above are on the school complex which has suspected mine waste use. Locations 1 and 3 are probably caused by gamma radiation from adjacent anomalies. The cause of elevated gamma exposure rates at locations 6 and 7 is not known.

Since nearly all of the PIC measurements were made on streets, there is a possibility that the measurements may be lower than adjoining areas. This is because the streets are paved or dirt and would have less retention of airborne deposition of mill wastes. In order to compare on and off-street exposure rate levels, all low outside gamma (LOG) measurements made at non-tailings locations during the 1978 survey were tabulated and ranked in Table 4. Like values were grouped and plotted on a log-probablity graph (Figure 4). The data points appear to fall in one distribution and have a slope or (SGD) of 1.1 indicating that they are ambient background measurements. The geometric average, or 50 percent percentile value, of the data points is about 13 μR/hr with a SGD of 1.1 μR/hr. There appears to be no statistical difference between the PIC measurements made on the streets and the corrected scintillometer measurements made in off-street areas.

These measurements do not imply that Edgemont or Dudley contain no airborne deposition of mill wastes. Large portions of 1st and 2nd Avenues in Edgemont were found to contain wind blown tailings during the 1971-72 survey.

Ten PIC measurements were made in a campground directly north of the mill site across the Cheyenne River. The corrected measurements ranged from 12 to 14 μR/hr. Some of the measurements were made on disturbed or bladed ground. The high PIC and a delta measurement were made on relatively undisturbed ground. Both measurements indicate surface contamination in that area probably caused by wind blown tailings. The term "delta" is defined in the next report section.

TABLE 4. LOW OUTSIDE GAMMA (LOG) SCINTILLOMETER MEASUREMENTS AT LOCATIONS WHERE TAILINGS WERE NOT USED - 1978 SURVEY

RANK	LOG (μR/hr)	CORRECTED LOG (μR/hr)	CUMMULATIVE %	LOCATION NUMBER
1	11	11	.75	7811 - 38
2	12	11.5	2.24	23
3	12	11.5	3.73	79
4	13	12.0	5.22	03
5	13	12.0	6.72	42
6	13	12.0	8.21	76
7	14	12.4	9.70	04
8	14	12.4	11.19	43
9	14	12.4	12.69	50
10	14	12.4	14.18	55
11	15	12.9	15.67	02
12	15	12.9	17.16	05
13	15	12.9	18.66	06
14	15	12.9	20.15	17
15	15	12.9	21.64	18
16	15	12.9	23.13	19
17	15	12.9	24.63	20
18	15	12.9	26.12	21
19	15	12.9	27.61	22
20	15	12.9	29.10	27
21	15	12.9	30.60	33
22	15	12.9	32.10	34
23	15	12.9	33.58	35
24	15	12.9	35.07	36
25	15	12.9	36.57	37
26	15	12.9	38.06	44
27	15	12.9	39.55	49
28	15	12.9	41.04	60
29	15	12.9	42.54	61
30	16	13.2	44.03	08
31	16	13.2	45.52	11
32	16	13.2	47.01	13
33	16	13.2	48.51	16
34	16	13.2	50.00	45
35	16	13.2	51.50	58
36	16	13.2	53.00	75
37	17	13.8	54.48	07
38	17	13.8	55.97	09
39	17	13.8	57.46	12
40	17	13.8	58.96	14
41	17	13.8	60.45	24
42	17	13.8	61.94	25
43	17	13.8	63.43	26
44	17	13.8	64.93	29

RANK	LOG (μR/hr)	CORRECTED LOG (μR/hr)	CUMMULATIVE %	LOCATION NUMBER
45	17	13.8	66.42	7811 - 31
46	17	13.8	67.91	32
47	17	13.8	69.40	40
48	17	13.8	70.90	48
49	17	13.8	72.39	51
50	17	13.8	73.88	52
51	17	13.8	75.37	53
52	17	13.8	76.87	57
53	17	13.8	78.36	63
54	17	13.8	79.85	77
55	18	14.1	81.34	01
56	18	14.1	82.84	10
57	18	14.1	84.33	15
58	18	14.1	85.82	28
59	18	14.1	87.31	41
60	18	14.1	88.81	46
61	18	14.1	90.30	47
62	18	14.1	91.79	54
63	18	14.1	93.28	56
64	18	14.1	94.78	81
65	19	14.6	96.27	30
66	19	14.6	97.76	59
67	19	14.6	99.25	78

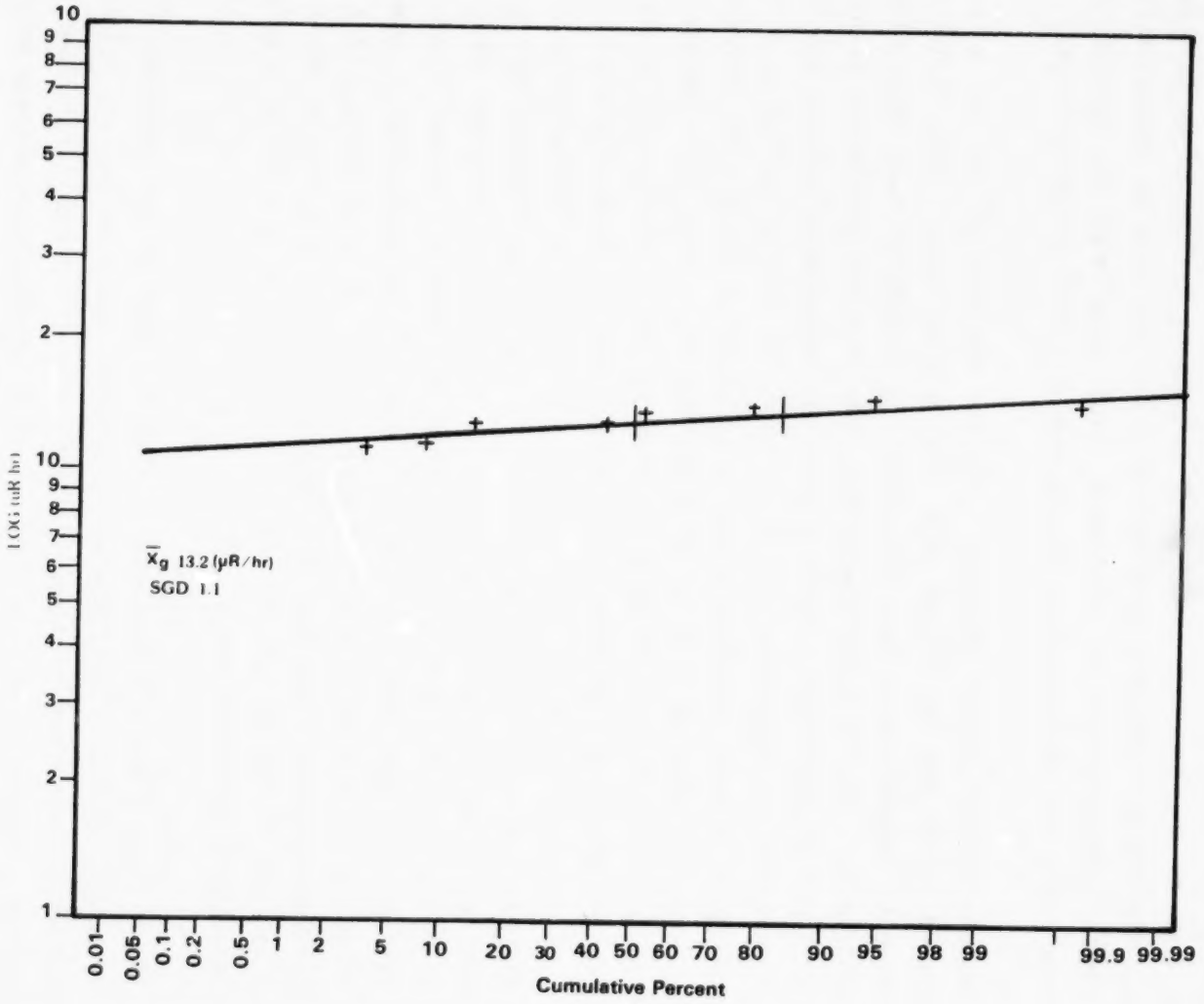

Figure 4. Log-Probability Plot of (LOG) Scintillometer Measurements

DISCUSSION OF GAMMA RADIATION MEASUREMENTS MADE IN COTTONWOOD DURING THE 1978 SURVEY

The community of Cottonwood is located to the southeast of Edgemont and adjacent to the Edgemont uranium mill site. Over 50 percent of the perimeter area of the developed portions of Cottonwood is bounded by tailings piles. The closest habitable structure to a tailings pile is approximately 150 feet. The location of Cottonwood, with respect to the surrounding tailings piles, has subjected this area to wind and water eroded tailings.

Because of the elevated exposure rates from the adjacent tailings piles, Cottonwood could not be logged with the scanner van. Some radiation measurements, however, were made with a PIC and a modified Rank Model NE148 scintillometer. The PIC measurements were made with the unit in the scanner van at street intersections. Figure 5 gives the measurement location and the gross corrected PIC measurement (i.e., corrected for the van shielding). The scintillometer used was modified to permit estimates of surface contamination while in the presence of an external gamma radiation field (i.e., adjoining tailings piles). The scintillometer's ratemeter time constant was increased to minimize subjective averaging by the operator and a sliding lead shield was added to the bottom of the instrument. The shield could be interposed between the instrument's detector and the ground. Two ground measurements were made at each measurement location: one with the shield away from the detector (open reading) and one with the shield under the detector (closed reading). The difference between the two readings (delta (Δ)) is indicative of ground contamination. The magnitude of Δ provides an estimation of the quantity of surface contamination. The relationship between Δ and above ground exposure rates as well as the quantity of surface contamination by mill tailings has been previously determined (Hans, 1977).

Figure 6 is a map of Cottonwood showing the location and magnitude of Δ measurements. Table 5 lists the 24 measurement locations and the scintillometer measurements made at three feet above the ground and the shielded and unshielded measurements made in contact with the ground. The average gross Δ value made over the Cottonwood area was 12. Assuming a typical background Δ

TABLE 5. SCINTILLOMETER MEASUREMENTS IN COTTONWOOD

LOCATION	3 FEET ABOVE GROUND OPEN SHIELD (μR/hr)	SURFACE OPEN SHIELD (μR/hr)	SURFACE CLOSED SHIELD (μR/hr)	(Δ) DELTA μR/hr
1	59	110	95	15
2	26	45	35	10
3	20	30	25	5
4	18	26	19	7
5	22	35	25	10
6	35	70	50	20
7	30	55	40	15
8	46	85	60	25
9	41	75	60	15
10	24	45	35	10
11	20	30	20	10
12	24	50	35	15
13	35	70	55	15
14	35	65	50	15
15	41	70	60	10
16	33	55	45	10
17	24	40	25	15
18*	20	30	25	5
19	20	30	27	3
20	22	35	25	10
21	28	55	45	10
22	50	100	80	20
23	28	50	40	10
24	22	40	30	10
Arithmetic Average	30		Arithmetic Average	12

* New Area for Mobile Homes

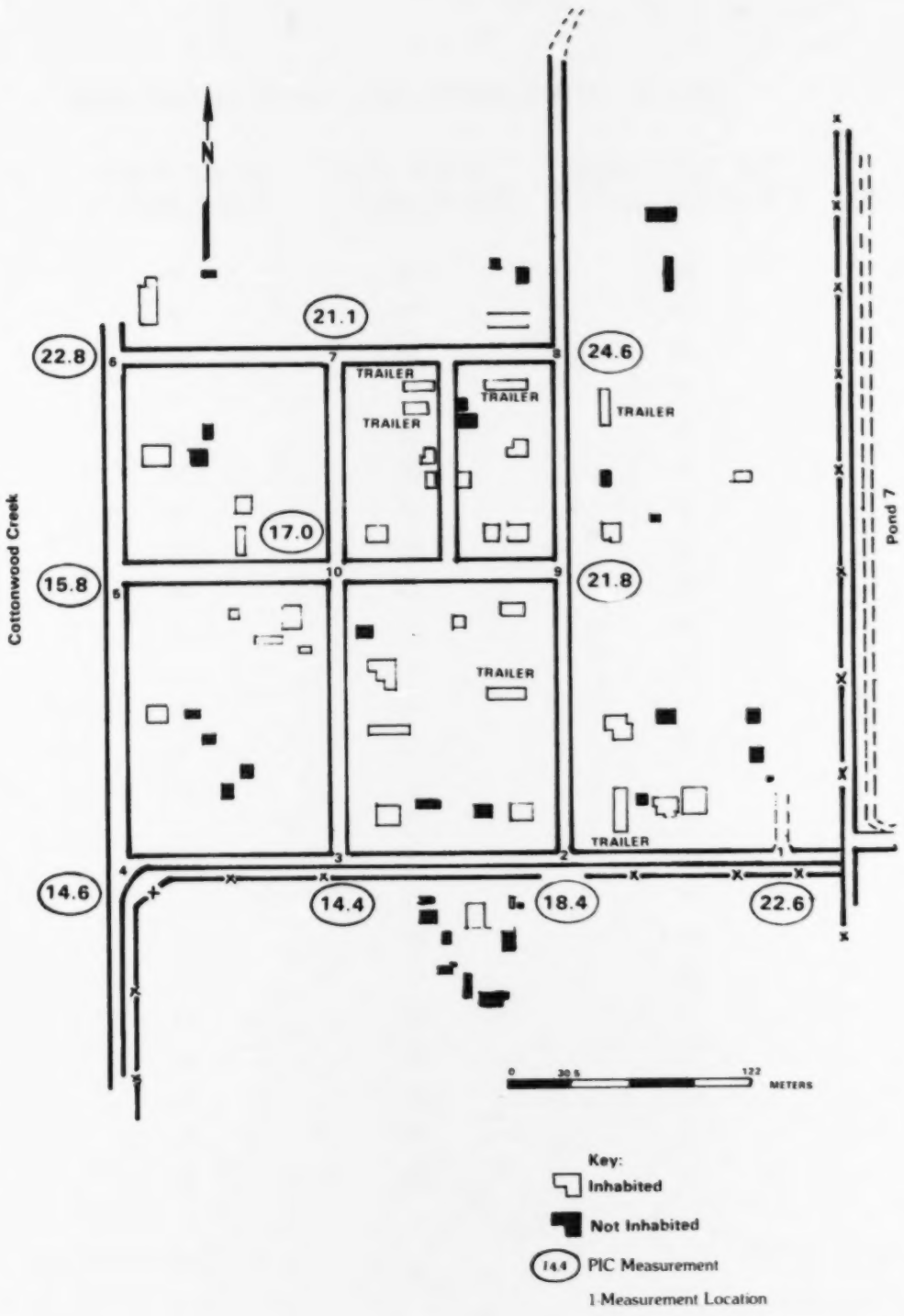

Figure 5. Gross Corrected PIC Measurements in Cottonwood

Figure 6. Delta (Δ) Measurements in Cottonwood

measurement of 4 for local natural soils, the net average Δ value for the Cottonwood area would be 8. This net Δ value of 8 corresponds to an estimated surface contamination of 50 pCi/cm^2 for radium-226 (derived from measurements made at other mill sites). Assuming a soil density of 1.6 g/cm^3 and the contaminants averaged over a depth of 5 cm, the radium-226 surface contamination would be equivalent to a net radium-226 concentration in the soil equal to 6 pCi/g. The net average above ground exposure rate estimated for the surface deposition is about 11 μR/hr. This agrees reasonably well with the average net corrected scintillometer measurements of 18 μR/hr for the Cottonwood area (i.e., 30 μR/hr - 12 μR/hr). It appears that most of the above ground exposure rates in Cottonwood result from surface deposition. The difference of 7 μR/hr between the estimated exposure rate from the average net corrected exposure rate minus the exposure rate from deposition may be due from "shine" from the adjacent tailings piles.

The arithmetic average of the net above ground exposure rates based on the corrected scintillometer measurements is 18 μR/hr. This amounts to an average annual exposure of 158 mR ranging from 53 to 412 mR for the Cottonwood area.

The average of the corrected gross PIC measurements made on the street intersections in Cottonwood was 19 μR/hr (Table 3). The average of the net PIC measurements is 7 μR/hr. The reason that the net PIC measurements do not agree with the average net corrected scintillometer measurements (i.e., 18 μR/hr) is that the streets probably contain less contamination than the adjacent vegetated areas.

In summary, most of Cottonwood contains eroded mill tailings and these tailings produce an annual net average exposure rate of 158 mR ranging from 53 to 412 mR. The average surface contamination, estimated from indirect measurements, is approximately 50 pCi/cm^2 of radium-226 averaging about 12 pCi/g. The Cottonwood population exposures to radon progeny and airborne tailings particulates were not evaluated.

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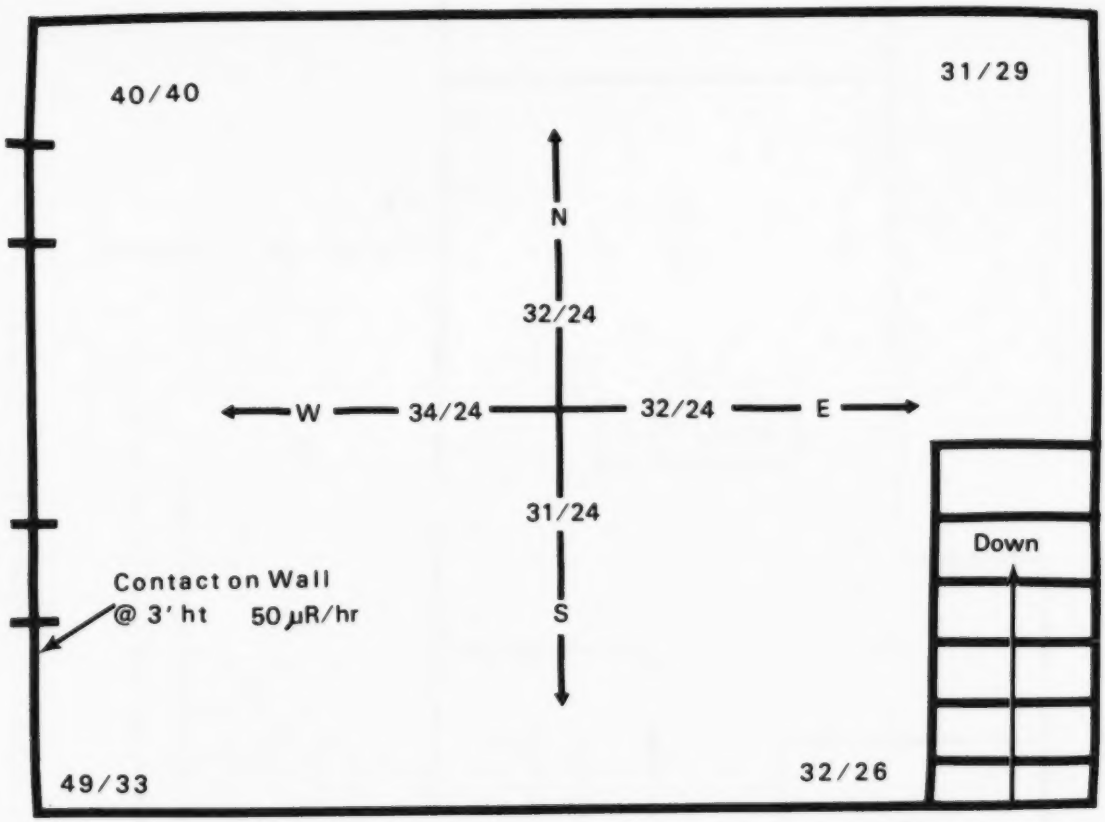
APPENDIX A

Sketches of Locations and Gamma Radiation Measurements Made During the 1978 Survey

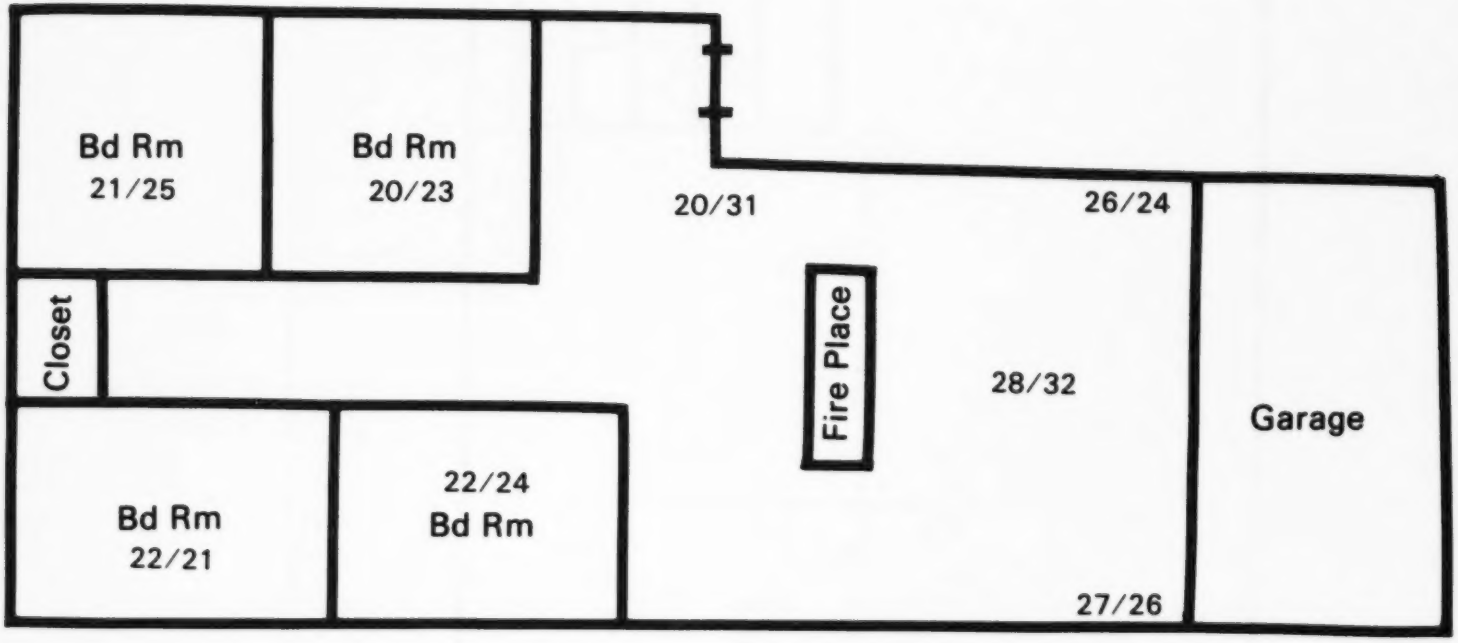


Key: $34^{x}/24^{xx}$

[x]3 Foot Measurement in µR/hr (Gross Uncorrected)

[xx]Surface Contact Measurement in µR/hr (Gross Uncorrected)

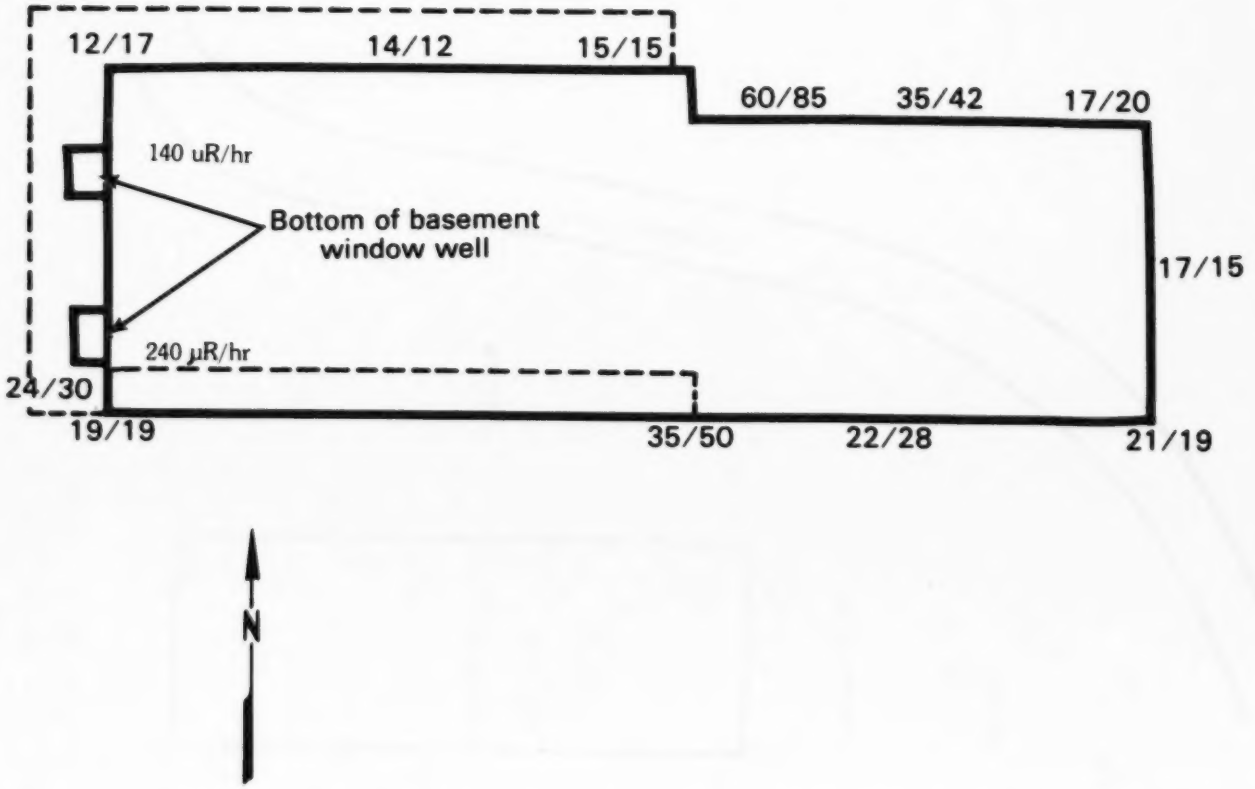
Figure A-2-a. Location 7811-80 - Basement



Key: $22^{x}/24^{xx}$

^{x}3 Foot Measurement in μR/hr **(Gross Uncorrected)**
^{xx}Surface Contact Measurement in μR/hr (Gross Uncorrected)

Figure A-2-b. Location 7811-80 - Main Floor



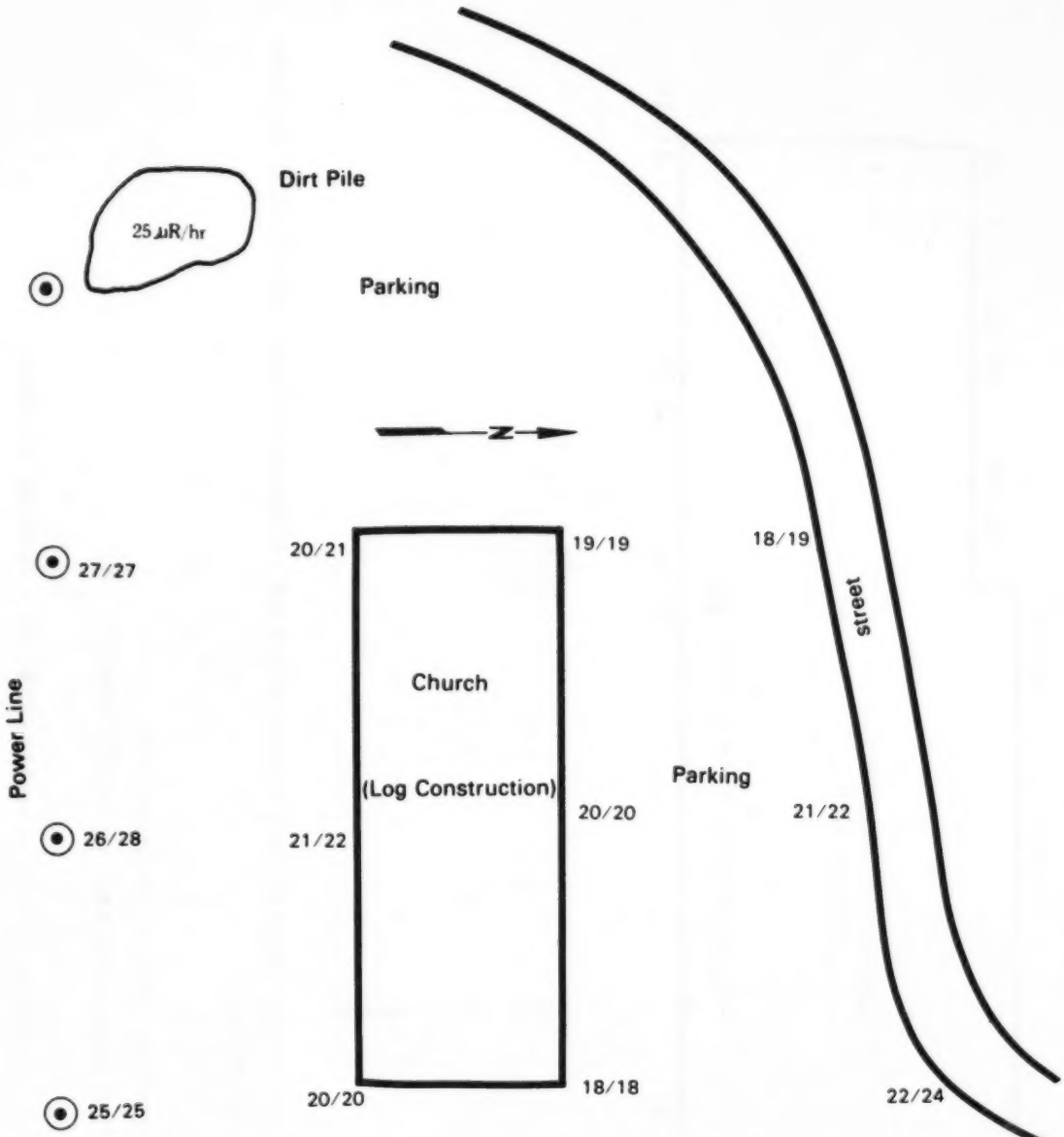
NOTE: SANDSTONE USED IN FIRE PLACE, YARD AND AROUND HOUSE MEASURED 75 µR/hr AT CONTACT.

Key: $14^{*}/12^{**}$

*3 Foot Measurement in µR/hr (Gross Uncorrected)

**Surface Contact Measurement in µR/hr (Gross Uncorrected)

Figure A-2-c. Location 7811-80 - Outside of House

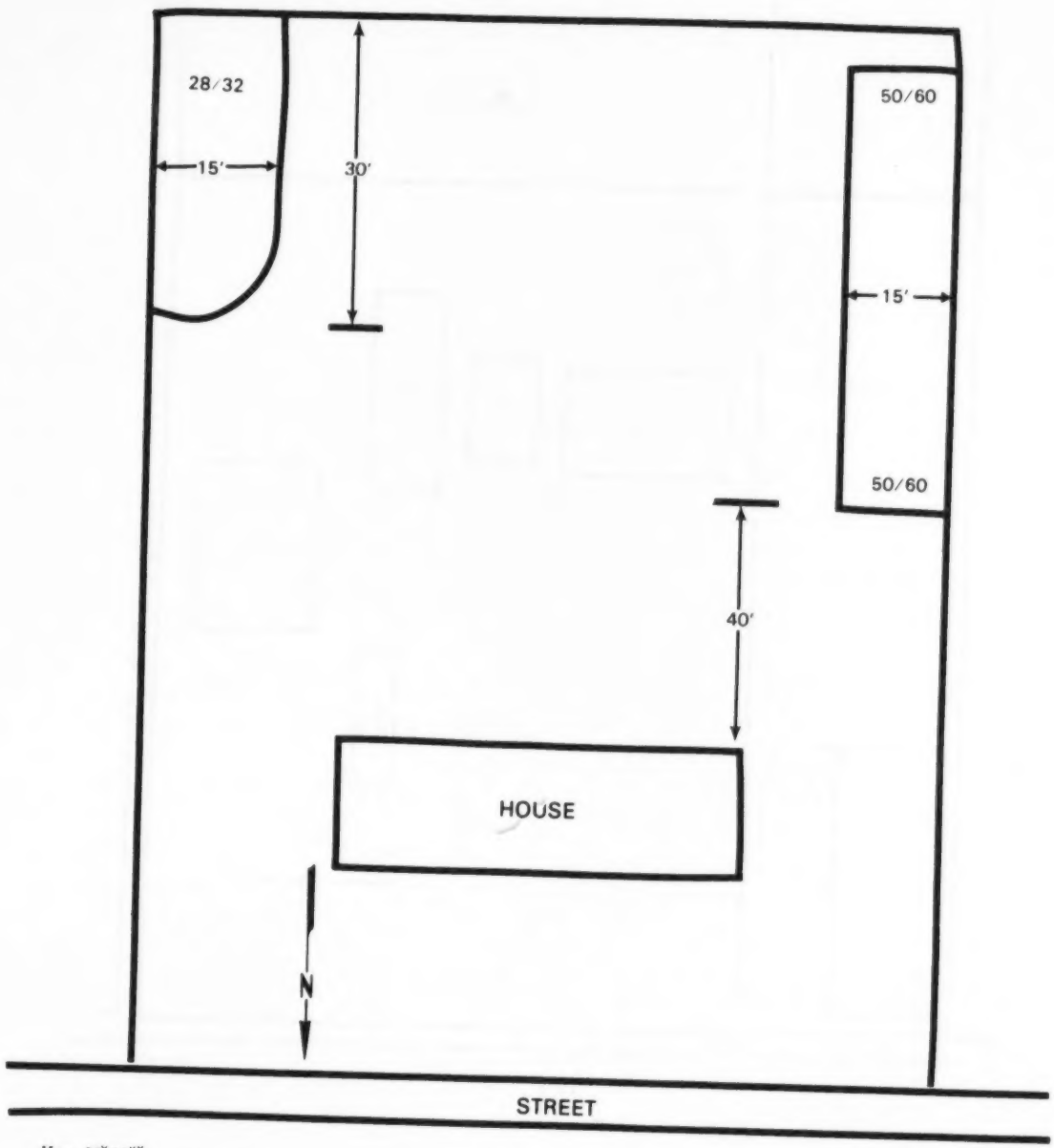


Key: $20^{x}/20^{xx}$

^{x}3 Foot Measurement in µR/hr (Gross Uncorrected)

^{xx}Surface Contact Measurement in µR/hr (Gross Uncorrected)

Figure A-3. Location 7811-81

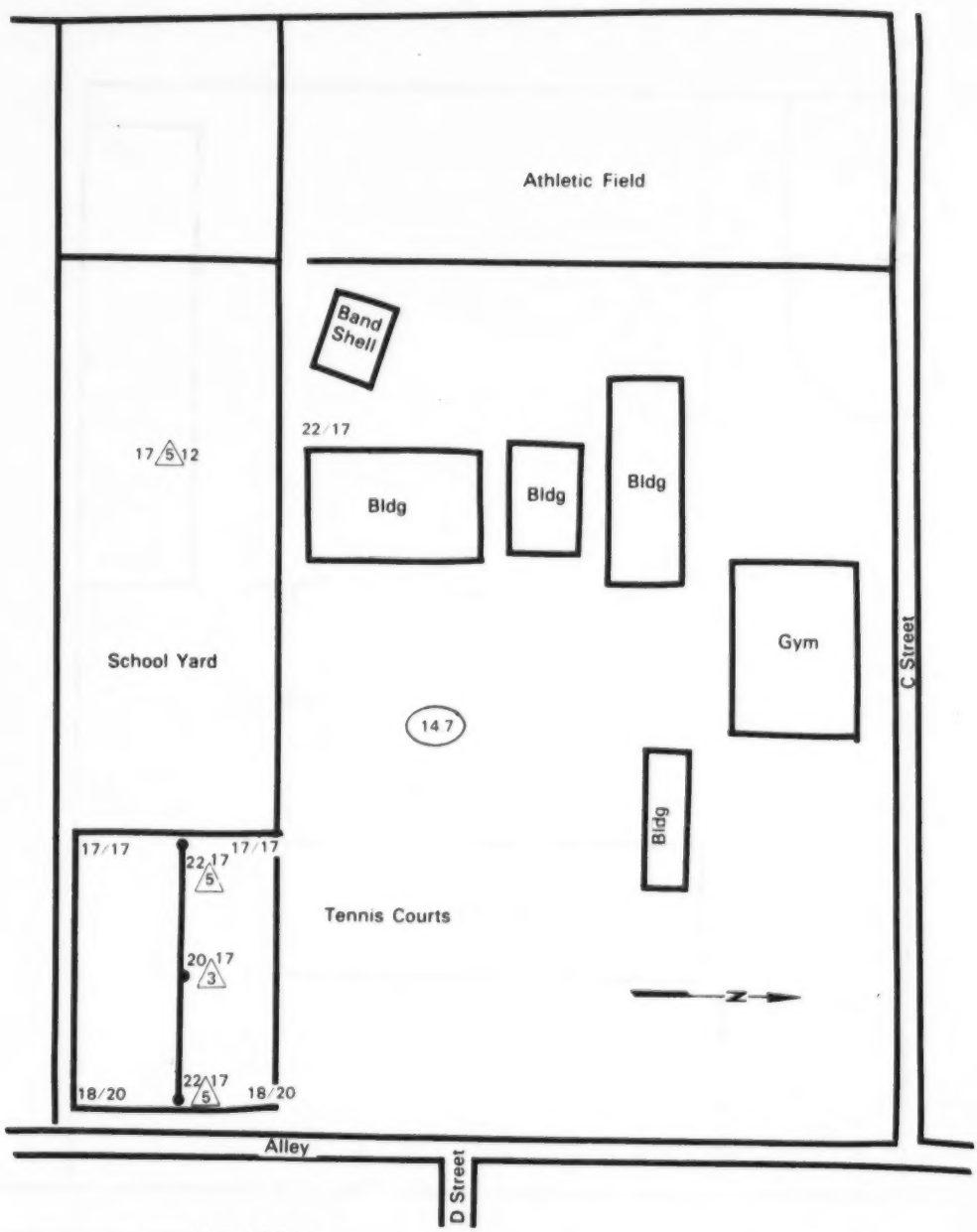


Key: $50^{x}/60^{xx}$

[x] 3 Foot Measurement in μR/hr (Gross Uncorrected)

[xx] Surface Contact Measurement in μR/hr (Gross Uncorrected)

Figure A-4. Location 7811-82



Key: 18'/20"
'3 Foot Measurement in μR/hr (Gross Uncorrected)
"Surface Contact Measurement in μR/hr (Gross Uncorrected)
Shield Open Measurement △ Shield Closed Measurement
Shield Open-Shield Closed
(14.7) - gross PIC (μR/hr)

Figure A-5-a. Location 7811-83 & 7811-63 - Edgemont School Area

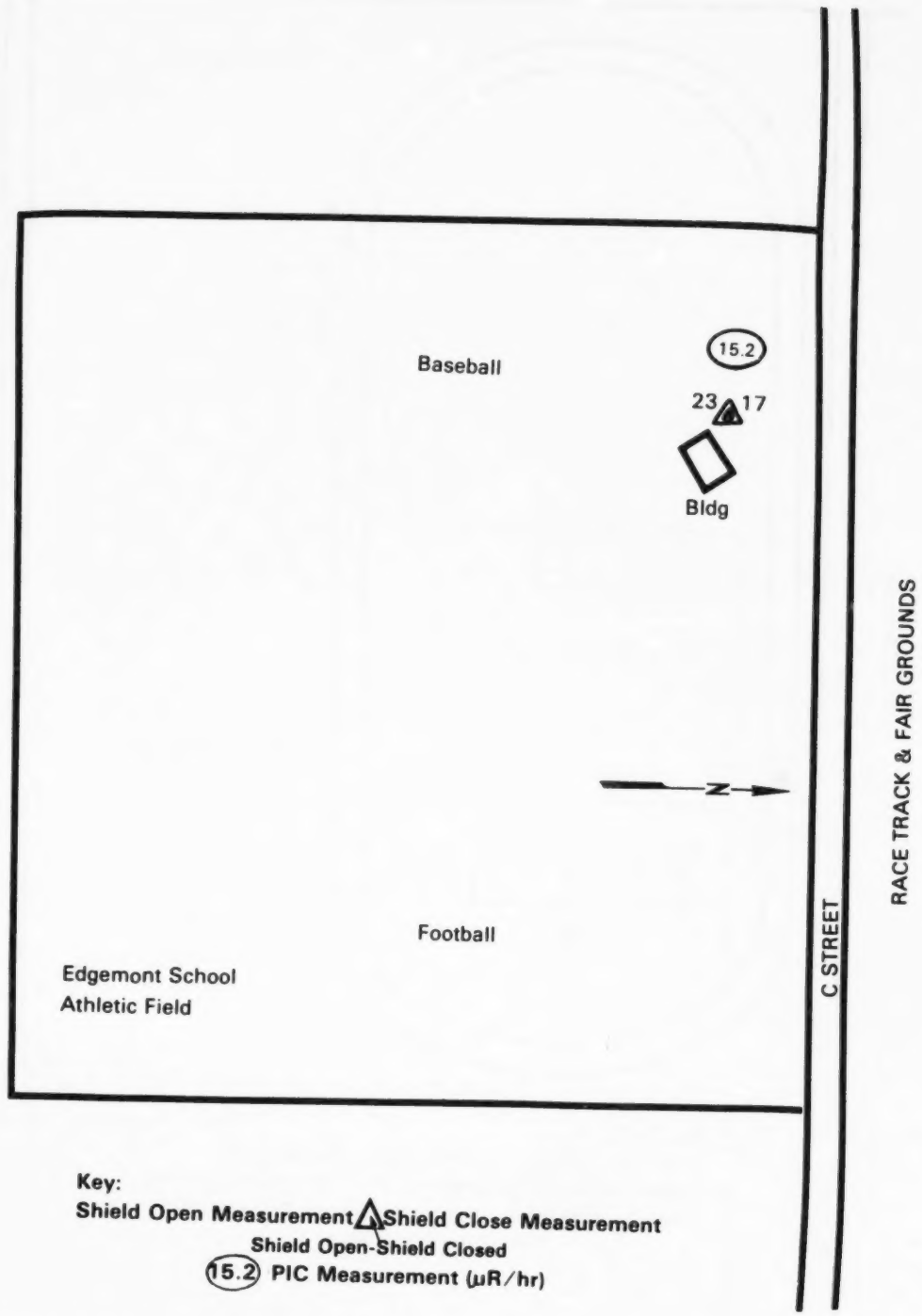


Figure A-5-b. Locations 7811-83 & 7811-63 - Edgemont School Area

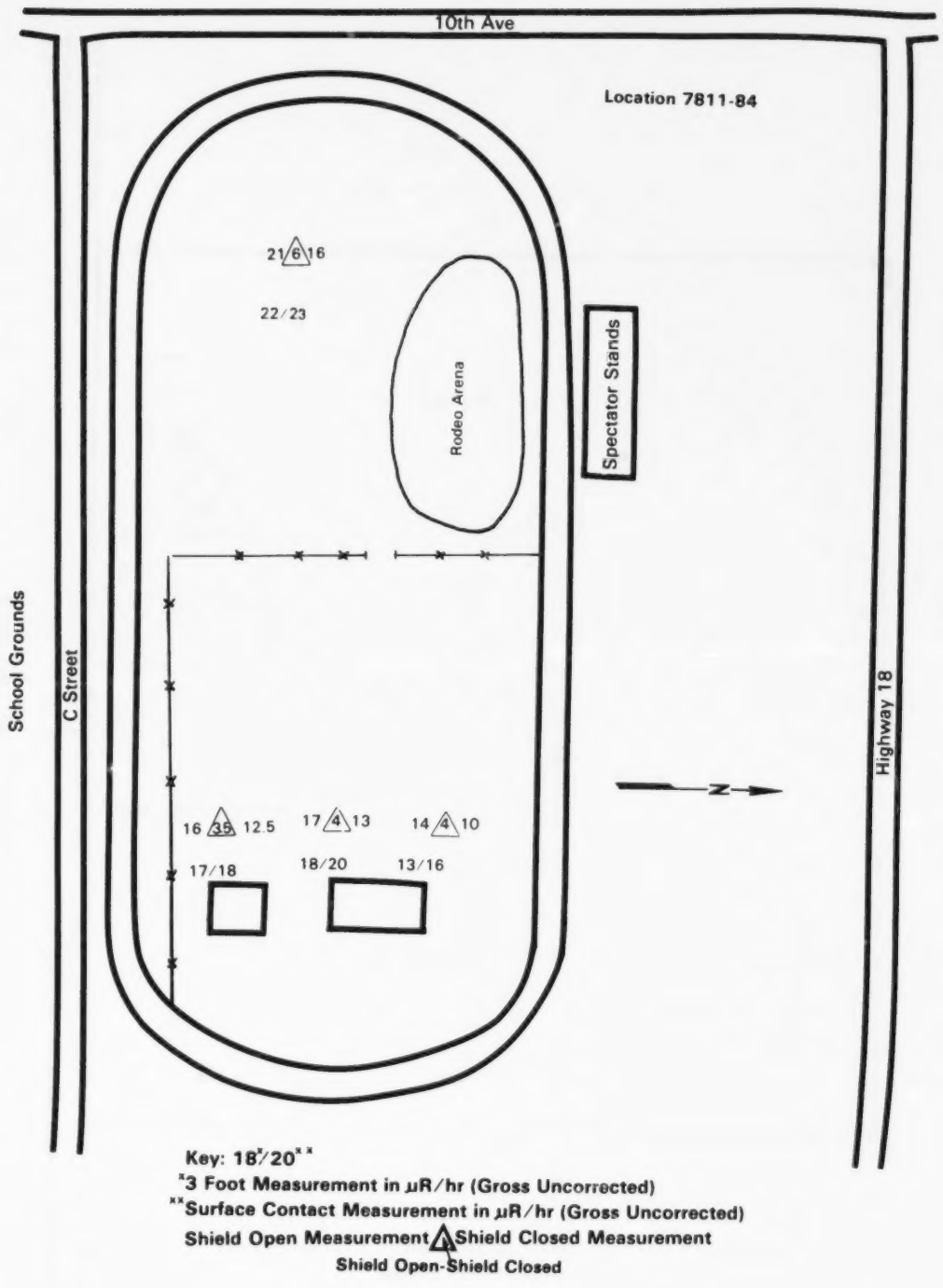


Figure A-6. Location 7811-84 - Fall River County Fairgrounds

APPENDIX B

Sketch of Edgemont Showing the Approximate Locations of Anomalies Found During the 1971-72 and 1978 Surveys and Gamma Radiation Measurements

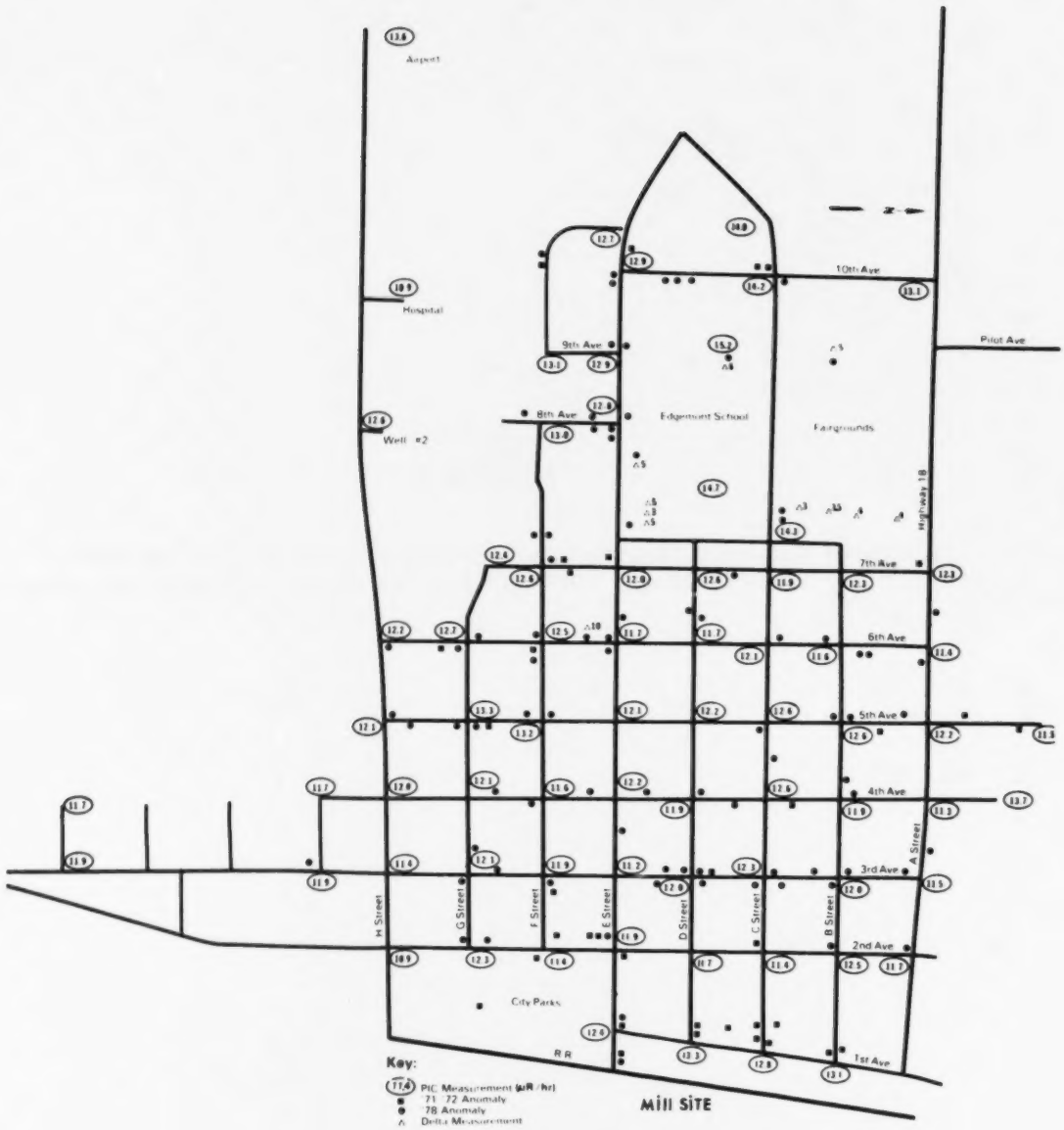


Figure B. Edgemont

APPENDIX C

Sketch of Dudley Showing the Approximate Location of Anomalies Found During the 1971-72 and 1978 Surveys and Gamma Radiation Measurements

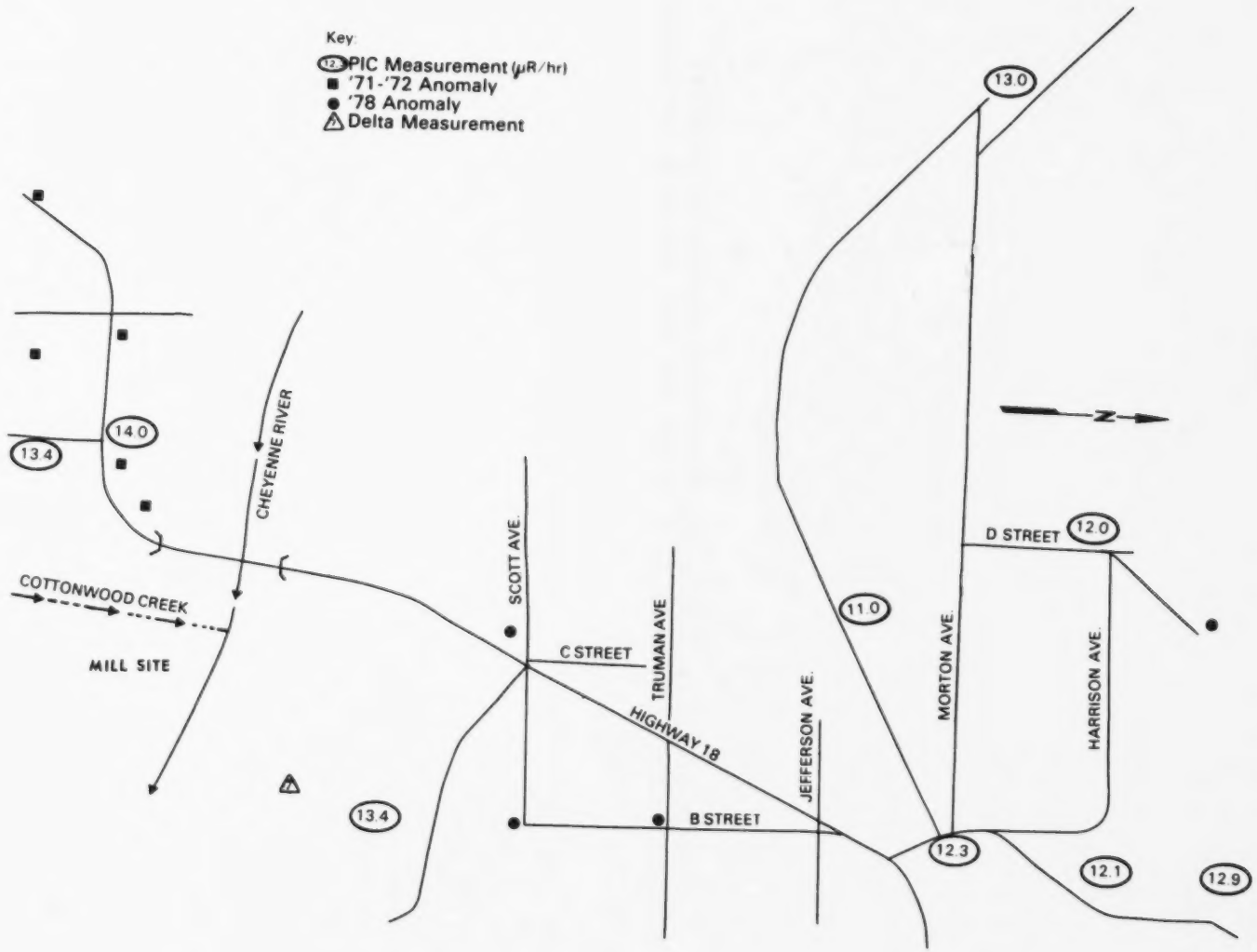


Figure C. Dudley

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